The Future of Reading Depends on the Future of Learning Difficult to Learn Things

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We are "reading" when we interpret meanings from phenomena. We read terrain, trails, the sky and clouds, faces, body language, art and iconography, books, movies and television, sounds, smells, and touch, external objects doing things, etc.

Here we are most interested in the fluent reading of human-made phenomena we call "writing": natural languages, mathematics, music, old and new computer-based media including user inter-faces, and other systems that attempt to capture, transmit and—most especially—explain important ideas.

Different representations for the "same idea" hold just parts of the idea, and condition the "reading" of the idea. For example, reading news in prose, poetry, and from a television set are very different experiences. Marshall McLuhan proclaimed that "You can argue about many things with stained glass windows, but Democracy is not one of them!" He meant both stained glass windows **and** television (our modern less beautiful equivalent).

Socrates' complaints about writing included "Writing removes the need to remember". He meant that a *prosthetic* brace on a healthy limb will induce withering. On the other hand, if we think of new technologies as *amplifiers* that *add* or *multiply* to what we already have rather than replacing them—then we have the opportunity to use writing for its reach over time and space, its efficiencies, and its ability to hold forms of argument that don't work in oral discourse. *And* we can still learn to remember all we've read! In other words, writing is not a good replacement for memories used in thinking—too inefficient—but is a great way to cover more ground, to cover different ground, and to have more to think about and with.

Plato must have enjoyed the irony of having his beloved mentor complain about the very medium that he brilliantly used to bring to us the ideas and personality of Socrates.

A big idea: there are not enough Socrates' to go around in any age, but the printing press could replicate Plato's compelling recreation of Socrates so that the printed books of the Dialogues in concert with more ordinary teachers could affect an entire continent and potentially enrich every reader.

We want to ask similar questions about what parts of great thinking and great thinkers can be captured by the new media of personal computers and pervasive world-wide networking—and what it takes to learn to read and write them.

It has been noticed in every age with reading and writing that these are generally more difficult for most people to learn than learning their natural language. This is a bit surprising given the initial 1-to-1 correspondence between speaking and writing. We will look at this a little further ahead. For now, we want to ask whether the difficulties are simply a problem, or whether conquering them might have some benefit. In other words—as with many technologies—we need to examine whether "easy to use" is a boon (it fits with our current abilities), or sometimes a snare (it keeps us the way we are or even makes us less).

Becoming a fluent reader and writer requires new and deep skills to be learned, to the extent that we are not the same human being afterwards. Anthropological studies of societies show that literate societies *think differently* than oral ones. In other words, a literate society is not "an oral society with a writing system" but is a new ecology of ideas and thinking.

McLuhan pointed out that what is most important about a communications medium is *what we have to become* in order to use it fluently.

The more different and difficult the medium, the less attractive—or even visible—it appears. Another McLuhan insight is that new media which are adopted at all first take their content from older and more familiar media. For example, it was important that the printed Gutenberg Bible be a Bible, and also *look* like a hand-made manuscript copy. Gradually, if the new medium has powers of its own, these will start to be found and used. The real message of printing was not to imitate hand-written Bibles, but 150 years later to argue in new ways about science and political governance. These are what forever changed Europe, and then America.

For example, the American system was *argued into existence* and shaped by writing and reading. Tom Paine's *Common Sense* was an argument *against* the commonsense of the day that "Monarchies seem natural" Instead he urged "We need to *design* our governance system". The Constitution was argued pro and con in the *newspapers* of the 13 colonies. The pro collection is "The Federalist Papers", and there is also a collection of "Anti-Federalist Papers".

The form of government was to be a republic—Plato again—but whose "guardians" were to be selected and—more importantly—dismissed by the entire population. This meant that the population of American had to be in the same discourse as the guardians. Thomas Jefferson said:

> *I know no safe depository of the ultimate powers of the society but the people themselves; and if we think them not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion by education.*

This is out of the scope of "stained glass windows"!

The reading skills in the population necessary to deal with these ideas in their original form are under great stress. The US Dept of Education assessment[i] of the adult population's ability to read well enough to follow these arguments revealed in 1992 that only 15% were skilled enough, and in 2003 this had dropped to 13% (where the drop was real and not noise). This isn't enough to support the original design.

But what do these figures actually mean? America is a complicated mix of populations, many in transition. A more telling statistic from the same Dept of Education study is an assessment of what percentage of graduates of 4 year colleges have the necessary skills. In 1992, it was only 40%. This is a jaw-dropper. How could 60% be awarded a college degree if they could not read at a "proficient" level? By 2003 the percentage has plunged to 31%. Beyond jaw-dropping.

By any measure, the future of structured prose reading could well be oblivion. It is hard to find and show all the reasons for this change. A simple one is that in the 19th century people read and wrote for all purposes when they had to transcend distance and time. As Neil Postman has pointed out, there were no competitors. This meant that when it came time to read and write for important purpose, a goodly percentage had the skills. In the 140 years since the invention of the telephone, many technologies have been invented that allow our more built-in propensities for oral communication to be extended over time and space electronically. Simple news and exchanges about the world and one's social acquaintances no longer require the deeper skills of writing and reading. That 22 minutes of news on television (it is like reading half a column in a newspaper) does not communicate much of importance has been ignored.

A number of excellent books have been written about "why reading and writing are harder to learn" than one's natural language. A recent good one is "Proust and the Squid"[ii] by the eminent neurophysiologist and reading expert Maryanne Wolf. This includes a good historical survey of writing systems, some of the latest brain science findings about reading and learning to read, and an outline of the process of learning to read for the majority of the population who are not lucky to be somewhat "prewired" for learning these skills.

For the purpose of this note, the reason we can readily learn natural language as children growing up in a language tradition—and other animals, even primates, can't—is that our brains, though very plastic in many ways, are still not a blank slate, but have structures that are set up by our genes to help us learn our languages. Even so, this is not done in a day, but takes years.

Oddly enough, even the idea of writing has not been obvious to our species for the 200,000 years we've been on the planet. As far as we can tell, the "real thing" is only about 5000 years old, and what should have been the most obvious way to do writing—making symbols for our speech sounds and "writing down the sounds" happened less than 3000 years ago.

Why is this? Because of the efficient processes we need for speech, our psychological experience is the hearing and expressing of *meaning* directly, and not piecing together sounds, and morphemes and words and parts of speech. And this is also the experience we have *after* we've learned to read fluently—or learned any other skill fluently: the parts of the skill are subsumed by what seem to be direct perceptions and doings of meaning.

Other "powerful ideas" have taken even longer to invent. For example, mathematical systems based on abstractions, premises, inference, and deductions happened in Greece after the alphabet was invented, and perhaps partly because of it. The Greeks had a few real scientists—Archimedes, Aristarchus, Eratosthenes, etc.—yet as far as we know they didn't really have "Science". But we don't really know details of the processes in the Alexandrian Age, and its great Library with mathematical and scientific librarians who presumably did try did check each other's ideas in ways we could consider scientific.

For us, "modern science" was invented in the 17th century, and its qualitatively different ways of thinking about the world, what evidence, knowledge, and argument—even "truth"—might mean, have quickly and qualitatively transformed our world.

The advent of science also transformed what was written and read, and what it meant to be a fluent reader and writer. For example, one of the most important books written in the history of humankind about important insights and discoveries is Newton's *Principia Mathematica*. To read it, one must be fluent not just in textual reading, but also in diagrams and mathematics. Today—in theory—a "literate" person should be able to read this book, but as C.P. Snow pointed out in his "Two Cultures" lecture[iii], this extension of what it means to be literate hasn't happened, even amongst many university professors.

Most of the 13% in America who can read Tom Paine's *Common Sense* cannot read books like the *Principia* (or much simpler, but still scientific expositions). This means that the actual percentage of potential voters in the US who can deal with the issues of our age is really only a few percent of the adults.

Another powerful perspective on the worlds we live in has arisen in the 20th century: Systems. In simplest terms, we humans are embedded in four great *systems of systems*: the natural universe, our social systems, our technological systems, and *ourselves*: "The systems we live in, and the systems we are".

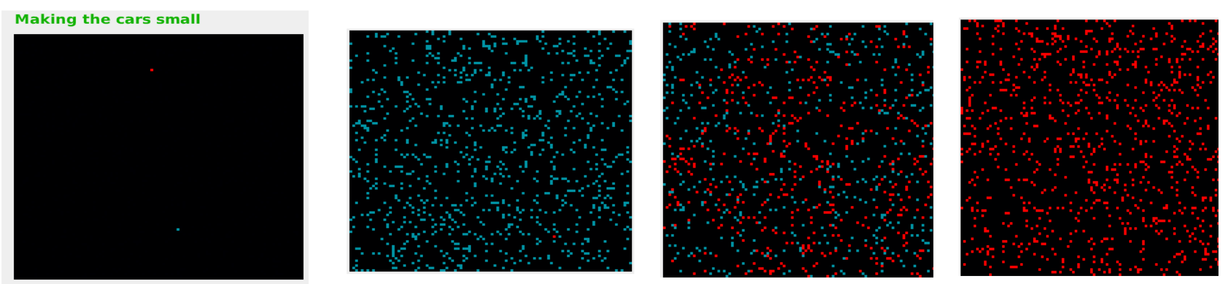
This way of looking at complexity has its own powers, outlook, vocabulary, dynamics, theories and principles. Many of the most important issues of the 21st century can be fruitfully examined through the eyes of systems organizations and dynamics.

Most systems have complicated interactions between their parts, and are very difficult to think about with our limited capacity brains, even with the help of modern mathematics. For example, many important systems in nature (e.g. climate, epidemics), society (e.g. early 20th Germany, contemporary Middle East, or U.S.), technology (e.g. Chernobyl), and our bodies (e.g. our circulatory system or glucose regulation) can be apparently stable for many years but then suddenly collapse into states that are debilitating and dangerous for us.

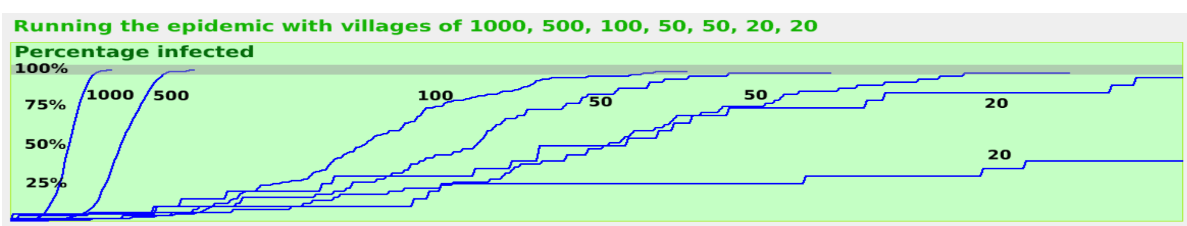
Today many of these vital systems can be understood and made more predictable. Systems became a more thinkable topic in the latter part of the 20th century because a medium for dealing with complex dynamic interactions was also invented in mid-century: the computer.

Some children are already getting "literate in systems". For example, a 10 year old child can paint a little graphical red car in Etoys[iv] and script it to move around.

A copy can be made with similar behavior and colored blue. A little program can be written by the child to see if a blue car and a red car have collided, and if so to turn the blue car red. The child can pretend that a blue car is a healthy person, and an infected person is red.



The child can make thousands of tiny blue cars and one red car, and set them loose to see the dynamics of an epidemic. The percent infected can be gathered and shown dynamically.



Different sized populations can be tried. The smaller the population the more sparse the "village" and the longer it will take for infections to happen. Children are fascinated by the variability of "luck". Still, all the villagers perish. Fast infections are like typhoid. Very slow ones are like AIDS. They can see that everyone will notice typhoid, but AIDS might seem to be invisible until too late.

The child has made a model[v] that helps create insight into why it is critical to pay attention to non-curable infectious deadly diseases no matter what commonsense seems to see. Millions of adults in the world, perhaps billions, do not have these insights, and are dying because of it. The child can post this simulation on the web—in a YouTube like site for children's creations—and other children can download it, think about it, make changes, etc.

From the standpoint of this note, we've now revealed a whole new set of *ideas* that we need to learn and think about—not just from the point of view of Science, but also the point of view of Systems—and we've added a new powerful and different medium—a dynamic medium for creative thought[7]—to the writing and reading skills we need to learn.

A "personal computer for children of all ages"—Dynabook idea—1968

The one laptop per child computer—2008

What do children have to learn to "write" their own epidemic simulation, and what do they have to learn to be able to "read" the simulations and similar creations by others? And how do we go about helping them to learn these new things? Can the computer itself help beyond being a wonderful new "stuff for making dynamic things"?

One can think of the computer as an extension of mathematics—it adds new ways to make models of things we want to think about. But we can just as reasonably think of the computer as a qualitatively new way to understand many kinds of complexity (it is a large enough idea that it constitutes a world of its own).

As Frank Smith[vi] has pointed out, all "literacies" first start with *ideas* we deem important enough to put effort into and desire to communicate them and our opinions to others (and just as importantly, back to ourselves). This gives rise to writing systems, then to learning processes for reading and writing, and these greatly *coevolve* with the ideas. A literacy and literature have been created.

At some point enough *new ideas* that strain the current system of thought will come forth to bud off into a new field of thought and very often new kinds of representational systems will have to be invented, leading to new notions of literacy and literature.

This brings us to a central point of this note: *The larger future of "reading" depends on the future of "learning difficult to learn things".*

Most of the invented "powerful ideas"—such as mathematics, science, equal rights, systems, musical architectures such as harmony and counterpoint, etc.—had to be *invented* because they are not strongly built into our genetically constructed brains. We can learn them to some extent because we can make structures and processes that are a bit like biological brains from internal representations in languages, and skills in manipulating the languages. For example, we aren't wired for the notions of *change* that Calculus was invented for, but we can get fluent enough in the artificial system of Calculus to outthink the greatest geniuses of antiquity in these areas.

In many respects, the main reason for structured education is to help people *learn difficult to learn things*. But many current educational systems miss understanding the actual states of "learners of *new*". Put simply: we are effectively blind, deaf, paralyzed, and without speech. As usual, McLuhan put it well: "Until I believe it, I can't see it". In other words *new* is by definition "something not encountered before", and what we can perceive, we do so because our minds have learned to see and hear and touch. And we can't talk about it well for a number of reasons. As master teacher Tim Gallwey[vii] has said, "One of the big problems with standard teaching is that most parts of the body and mind that need to do the learning can't understand English!".

There are issues of capacity—e.g. George Miller's 7±2 chunks[viii]. When we start to learn something new we have very weak representations and are quickly overwhelmed. The pace of creation, consolidation and growth of chunks has to be careful managed.

Cesare Pavese said "To know the world, one must construct it". He meant both mentally and, in many cases, physically. The great 20th century composer Paul Hindemith explained the relations between music and human participants as "cocreation". That is, what is actually going on in Art, and learning in general, is not simple "white rat reflexes" but the *making* in one's mind of our own version of what we are trying to perceive and do.

If we combine the last two paragraphs we can see how some of the difficulties of learning and teaching arise. We have a lot of trouble dealing with "*the it*", yet we somehow have to make versions of "*the it" that aren't yet "it" in order to get to "the it"*. For *learning difficult to learn things* this can be a long and often painful and discouraging process even when unnecessary difficulties have been removed from the experience. There are still real difficulties, and these can require many hours—often thousands of hours—to create the internal parallel mental "agents" that start to act like parts of our own nervous system as skill is acquired.

Moreover, each of us comes to a particular subject with different predispositions, both genetic and from experience. Some will need very little help, some will need some help, and some will need a lot and different help. Some will be very motivated, some will not be at all interested.

Combining these two, it is not hard to imagine at least 15 to 25 "kinds" of learners which educational processes need to deal with. Despite this, most educational systems have just one curriculum and process for all. Part of this stems from an ironic kind of ignorance, but much of it are consequences of both tradition and economics: the tradition of having one teacher for a subject many days in a row, accompanied by economic and "economies of scale" arguments.

In a very different approach, most music and sports learning only has contact with a one-on-one expert once or twice a week, lots of individual practice, group experiences where "playing" is done, and many years of effort. This works because most learners really have difficulty absorbing hours of expert instruction every week that may or may not fit their capacities, styles, or rhythms. They are generally much better off spending a few hours every day learning on their own and seeing the expert for assessment and advice and play a few times a week.

A few universities use a process like this for academics—sometimes called the "tutorial system", they include Oxford and Cambridge Universities in the UK.

This "more private work but with weekly expert critiques and advice" process is quite important.

> Another pause point in this note allows us to reflect that: *"The future of learning difficult to learn things depends on the willingness of learners to spend many hours over years getting fluent"*.

We could add to this: "… And on the ability and willingness of society to motivate learners in many different ways to want to put in those many hours".

As far as the weekly expert advice, one would be upset to take a tennis lesson and not have the pro play with you (or even be able to play). Or to have a piano lesson from a teacher who doesn't play or who won't play with the students. For one thing, how can they really assess the learner's current state? What kind of message and motivation is given if the expert obviously doesn't love the activity enough to want to do it? But of course this happens all the time in traditional education.

Compared to many official educational processes, for many subjects it is preferable to use the "Socrates in a book" approach that transformed Western thought. This is at least one-on-one, paced to the learner, and the kind of writing that transforms our thinking. But, in the end, this doesn't have enough feedback, and often not enough "making" to really help the learner learn a difficult to learn thing. More is needed.

But what about "Socrates in a *computer*"? Something more than "Socrates in a book" should be possible here, because the computer is active and can sense many things that the learner is doing: where they are looking, how interested they are, hesitations and confidence, and much more.

What can be done now? And what are the future scope and limits of the computer as a "superbook", a "dynamic book"—a *Dynabook*![ix,x]—that is both a *meta-medium* which can contain all media—especially media that cannot exist without a computer—and a comprehensive guide that can help learners learn difficult to learn things?

Questions that have to do with social motivation and charismatic teachers, etc., have been difficult to answer over the almost 6 centuries that we've had the printed book. There are many reasons why a person might want to learn to read, and then to read to learn, and we can't assign any intrinsic properties to a medium like a book or a computer where we can claim that their very presence will motivate all to learn what they *need* rather that just following what they *want*. A large part of what education means in any society is to successfully get people to *want what they need*. We can look at the history of the book and see some of the tradeoffs—including the cautionary tale of Madame Bovary—and we have no doubt that most of these will apply to the use of computers as a writing, reading and publishing medium.

These issues are difficult. What we can discuss is what computers should be able to do besides holding and displaying representations of past and computer-only media.

Many of the present author's notions about what personal computing could and should be were shaped in the 60s by reading about ideas for learner-driven learning environments, especially by Maria Montessori[xi], the patron saint of these ideas writing at the beginning of the 20th century, O. K. Moore in the early 60s, and Seymour Papert a few years later.

Montessori was a special kind of genius who cannot be summed up in a few words. In working with children as a physician with an extensive background in psychology and anthropology, she made a deep connection between how children are driven by their genetic heritage to learn their language and culture from their environment, and had insights that schools could be set up in very similar ways. She said: "We are in the 20th century, yet the environment for the children at home and school is more like the 10th century. What would happen if we embodied the powerful ideas of our time in the *environment* in which children naturally grow?" Some of her environmental ideas were manifested in the physical objects in the Montessori classrooms, especially in the special toys she devised for the children that had deep learning side-effects through play. Another set of environmental ideas had to do with how the children were treated, and how they were expected to act and cooperate. This worked extremely well! The children readily took on the processes, ideas and spirit of this new educational design.

O.K. Moore was a psychologist who was interested in somewhat similar ideas while at Yale in the early 60s[xii]. He defined a *responsive environment* as one that:

1. permits learners to explore freely
2. informs learners immediately about the consequences of their actions
3. is self-pacing, i.e. events happen within the environment at a rate determined by the learner
4. permits the learners to make full use of their capacities to discover relations of various kinds
5. has a structure such that learners are likely to make a series of interconnected discoveries about the physical, cultural or social world

He called such an environment: "*autotelic*, if engaging in it is done for its own sake rather than for obtaining rewards or avoiding punishments that have no inherent connection with the activity itself[xiii]". By "discovery" he meant "gently guided discovery" in the sense of Montessori, Vygotsky[xiv], Bruner[xv] and Papert[xvi]: (i.e. recognizing that it is very difficult for human beings to come up with good ideas from scratch—hence the need for forms of guidance—but that things are learned best if the learner puts in the effort to make the *final* connections themselves—hence the need for processes of discovery).

Moore aimed his efforts at inventing and making an *autotelic responsive environment* that would help young children learn to read via learning to write. He wanted to harness children's desires to be active-agent creators with a sense of both art and learning to do their own shapings. This shouldn't be such an "aha" because children need to do a lot of talking in order to learn their native language.

In the early 60s, Moore devised a "talking typewriter" that could react to what very young children typed on it (at first it was a Selectric typewriter in a room with a grad student in an adjoining room with a microphone watching what the child is doing and reacting to it). The room had no distractions other than the typewriter, and this was an important part of the design (looking back from our experiences today it should not be necessary to spell out why this is critical!). The guides to this environment were other children, not adults.

The "talking typewriter" learning room

Writing by a 1st grader

We went to Boston and when we were driving we had to stop to have supper. We stayed with some friends. When we got there it was ten o'clock -- way past our bedtime. We woke up Mom and bothered her. I mostly watched TV. Daddy watched TV with me and Mom talked with Ellie Friess. When Daddy was not watching TV, he was talking to Uncle Al. We had fun!

Writing by a kindergartner

Mother is well now. The cast is off her leg. Now she can drive me to school. I am glad.

Writing by a nursery schooler

Pam, you could be a nurse someday. But when you be [sic] a nurse, you cannot scream like you do now.

One of the interesting rules of the environment is that children can leave any time they want, but they then cannot come back until the next day (this is very similar to one of Montessori's principles about choice of toys).

The larger curriculum that Moore devised was rich and extensive, and encompassed most aspects of language learning including literacy. The key was how the "typewriter" responded to their actions to encourage them to start to write words that they knew. Children have an *urge to make* and they loved to read words and sentences that they wrote. This expanded into desires to read everything, Many of the ideas here followed the same lines as later suggestions of modern learning to read experts such as Wolf.

The "larger" (or "transfer") activity for these 4 and 5 year olds was to be a reporter on a newspaper and write stories about what they thought would be interesting news. The editors of the paper were first graders. As one might hope, the results were spectacular. (It is worth imagining these young children in the early 60s dealing with mimeograph and hexograph machines with the help of adults!)

Moore's prescient ideas were much too early for the computer technology of the day. But today they are as sound as ever. The best of the ideas have to do with how to harness the intelligence and drives of the learners to provide deep interior motivation for many hours of learning and practice. (A few of these ideas were used in the original PARC GUI—and we very much wanted to get to "responsive" not just "reactive", but our level of understanding how to do this was not yet developed enough.)

Moore's ideas have been tried several times since—a large scale effort was IBM's "Writing to Read" done in the mid 80s with the advent of the PC computer[xvii]. This had considerable success but was still quite expensive in most dimensions.

Today a real " 'talking typewriter' with subject matter helper agents" is well within the reach of a large research effort, similar to that which catalyzed the invention of the personal computer and Internet in the 70s. Moore's approach was full of exemplary ideas that can be used today, and there are far too many for inclusion in this note. Instead, let us think of them as part of the larger context that is needed to take personal computing closer to its most important destinies.

Seymour Papert, a mathematician who had studied with the child psychologist Piaget, created a programming language for children that embodied advanced mathematical ideas in forms that matched well with children's minds. The way of scripting the car in the previous epidemic example was influenced by Papert's ideas. Children learned deep mathematics by *making* the math themselves via *writing programs* which were "real math that the computer could bring to life". Once again a new future of reading and writing (and reading *via* writing) had been invented.

This brings us to another main point:

> The future of learning difficult to learn things is the future of *learning to make difficult to make things*—in other words, the future of "reading" depends on the future of "writing".

A critical and provocative insight is that many of the processes needed for learning reading and writing along these lines are quite adaptable to learning mathematics, music, computer creating, even science and engineering (the latter "even" because the sensing problems for children doing investigations and constructions in the real world are much more difficult than when the world of interest is entirely on the computer). For example, what is our child now doing over in the corner with white powder and a dark liquid. Is it baking soda and vinegar or something else, etc.?

This is the heart of what personal computing really is about, and especially highly portable personal machines like the Dynabook idea. Though parts of the idea and fit to human beings have to do with the physical form and feel of the device, 95% of a real Dynabook design lies in the richness of the services it can provide to its owner, and the first of these is an interface that can facilitate learning, not just reactions. This is why the present author has responded to questions about various consumer devices "Isn't this (e.g. the iPad) a Dynabook?", by saying "No. It has more capacity than what was imagined in 1968, but it still lacks the essential services and guides for its owner".

We've looked at the past and the present of technology-assisted "learning to 'read' and 'write' " environments. What are the realistic prospects for getting to the next level of embodying active teaching and learning in computer technology? For example, let us suppose we have gained considerable experience helping people learn a subject using human teachers and coaches, and we wish to make a computer environment that can do as much as possible without an expert human teacher to help. Further, we will restrict ourselves to subjects whose worlds can reside entirely within a computer, such as: reading and writing, mathematics, and computer use and programming. We aim for a computer learning helper agent that is better than no teacher, better than a bad teacher, as good as a decent teacher, and will not attempt the magic of a great teacher.

We need at least:

1. To see and interpret what the learner is doing and feeling
2. To be able to communicate in the usual human modalities
3. A good model of the subject matter
4. A good model of how the subject matter is best learned by a variety of learners
5. A good model of human commonsense reasoning, to put the tutoring agent as much as possible in the same world as the learners
6. "Relationship theories", e.g. strategies that avoid becoming a prosthetic for the knowledge, but which constantly move towards helping the ideas and skills get built inside the learner
7. Authoring systems for "teachers of the computer agents" that allow content and pedagogical experts to inform a general tutoring system about specific subjects and methods of approach.

It's easy to see why this has proved a very difficult problem over the last 50+ years that it has worked on! But progress has been made on many parts of our requirements:

a. It is now possible to use the video cameras on our computer to do real-time tracking of where the learner's eyes are looking, the degree of interest in what is going on (pupilometry), and facial recognition and expressions. We can listen not just to what the learner is saying, but to some degree assess parts of psychological state.
b. Computers can understand to a better degree highly contextualized speech and written language, and also produce it.
c. Good computer models have been made of some subjects—for example Geometry[xviii], some story structures, parts of programming languages.
d. We still lack deep computer models of how subject matter is best learned by a many kinds of learners.
e. We now have extensive working models of human commonsense reasoning[xix].
f. We lack examples of how to avoid "the Siri syndrome" of the computer as servant, and how to "convince the learner to want to learn to ride a bike rather than to drive a car".
g. Authoring systems for computer tutors at this point require expert model builders and many person hours of many kinds of people in order to produce a somewhat workable experience for a learner.

Of course, having parts does not remotely give us a simple route to making a whole, especially when the combination is very complex and intertwined. However, in some cases it is easy to see how some of the parts can help the others. For example, a good working model of human commonsense world view and reasoning can be used to add needed depth to attempts to understand what a learner is doing, saying, asking, needing. A commonsense reasoner—such as

CYC[13]— can rephrase ambiguous questions from the learners into three or four unambiguous questions and ask which one was meant[xx].

A number of successful tutors have modeled human teachers, but in a very expensive and ad hoc way: for example the systems built using the ACT-R system by Anderson, Koedinger[12] and others. More recently, carefully built systems by Acuitus[xxi] have produced reports of impressive results. These systems are generally case-based with many thousands of hand-built cases, and are quite expensive. However, for mass audience subjects—such as early reading, 3rd grade arithmetic, 9th grade algebra, first courses in computer programming, etc. the costs can be amortized over an entire nation of learners. This is worth doing because achieving a good feel and fit in the user interface dynamics reveal what needs to be accomplished, and can lead to more compact more automatic ways to create the same systems. Despite the immediate and long term benefits governments have been loathe to invest in this learning curve.

An important way to think about these issues is to realize that of all the necessary inventions that contributed to the success of personal computing, the gateway for its billions of users has been the graphical user interface, which acts as a usable, often pleasurable, now usually invisible intermediary between the two very different worlds of human beings and what is actually going on inside the computer.

User interface style and experience has not advanced materially since *reactive* graphically based interfaces were invented by the ARPA/PARC research communities in the 60s and 70s. Even a seeming interface agent, such as *Siri*, is mostly a simple extension of user search and alerts that have been part of reactive interfaces for decades.

This style of communicating between humans and their computers has proved to be very powerful, almost universal, and relatively easy to use. But it is far from what is possible and, more importantly, what is needed.

> The next qualitative advance in user interface environments will be: *a teacher for every learner*—user interfaces that can deeply help end users learn new ideas and whole subjects.

Besides the obvious simple benefits of such an advance, this also allows new inventions to be put out to the general public that do not have to (a) follow one style groove for many decades, or (b) to be aimed at the lowest common denominator of learning and intelligence. Part of a new idea—whether application or how to be more facile on one's computer—can be the "advice to the user interface" about how to help the end user learn the new ideas.

> This means that *the real computer revolution hasn't happened yet*.

And, that we will miss it if we can't think beyond the long present that was created by a few inventions 40 years ago. One of the ways to do this is to "cross out the present" and try to move beyond what we believe we *want*, to think about what we actually *need*. Only then can we understand the future powers of technologies in the grand tradition of writing and the printing press to amplify the best parts of our nature and help us move beyond our genetic cages to a our more enlightened destiny.

Notes and References

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Alan Kay Bio

For pioneering personal computing, object-oriented programming, and graphical user interfaces, he has received the Draper Prize from the National Academy of Engineering, the Turing Award from the Association of Computing Machinery, and the Kyoto Prize. He has been elected a Fellow of: American Academy of Arts & Sciences, National Academy of Engineering, Royal Society of Arts, American Association for the Advancement of Science, and Computer History Museum. Other honors include: ACM Systems Software Award, NEC Computers & Communication Foundation Prize, and numerous honorary doctorates. Alan has held Fellow positions at HP, Disney, Apple, and Xerox, and has served as the chief scientist at Atari. He is an adjunct professor of computer science at UCLA and an advisor to One Laptop per Child. At Viewpoints Research, he continues his work with "powerful ideas education" for the world's children, as well as the invention of advanced computing systems.